SUSPENSION DESIGN AND PERFORMANCE

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SYNOPSIS

Some of the fundamentals of heavy vehicle suspension design are discussed as are some of the reasons why there is a need in New Zealand for locally designed and manufactured trailers, as well as the reasons for modifying existing vehicles. A tandem axle suspension using rubber bolsters was designed by the DSIR and this is used as an example of the approach used by AIDD in the design of suspensions. The steps taken can be summarised as:

(a) Setting the parameters for the design. This involved testing an existing suspension.

(b) Prototype design. This stage is gone into with some depth. Such things as static and dynamic loads, as well as suspension geometry are dealt with.

(c) Prototype testing, i.e., the verification - or otherwise of the engineering assumptions and calculations which have been made.

(d) Redesign. Using the data which has been gathered from the testing to refine the production prototype.

1. INTRODUCTION

1.1 Background

It is common knowledge to the transport industry that maximum vehicle and axle weights on New Zealand roads differ from those used overseas. In most cases the maximum allowable loads are less in New Zealand than they are overseas. Because of this it is quite common for example to have a vehicle with the standard suspension designed for rear axle loadings of up to 20 tonnes where the maximum allowable load is only 14.5 tonnes. It is also quite common to take an imported vehicle, designed for a certain payload in its original home market and then to add an extra axle to allow it to carry the same load on New Zealand roads.

We therefore have the situation which may not be obvious to those outside the transport industry where it is desirable to make large modifications to heavy vehicles imported from overseas. We also have an environment where it makes sense to manufacture our own local heavy trailers.

At the DSIR we have had a continuing association with the local transport industry and some of this has involved the design of vehicle suspensions.

1.2 A Case Study

A suspension we were asked to develop was a minimum weight tandem axle unit rated at 14.5 tonne ground load and based on commercially available rubber springs (see figure 1). This paper will go into some of the basic principles of design and how these were applied at AIDD using this project as an example.

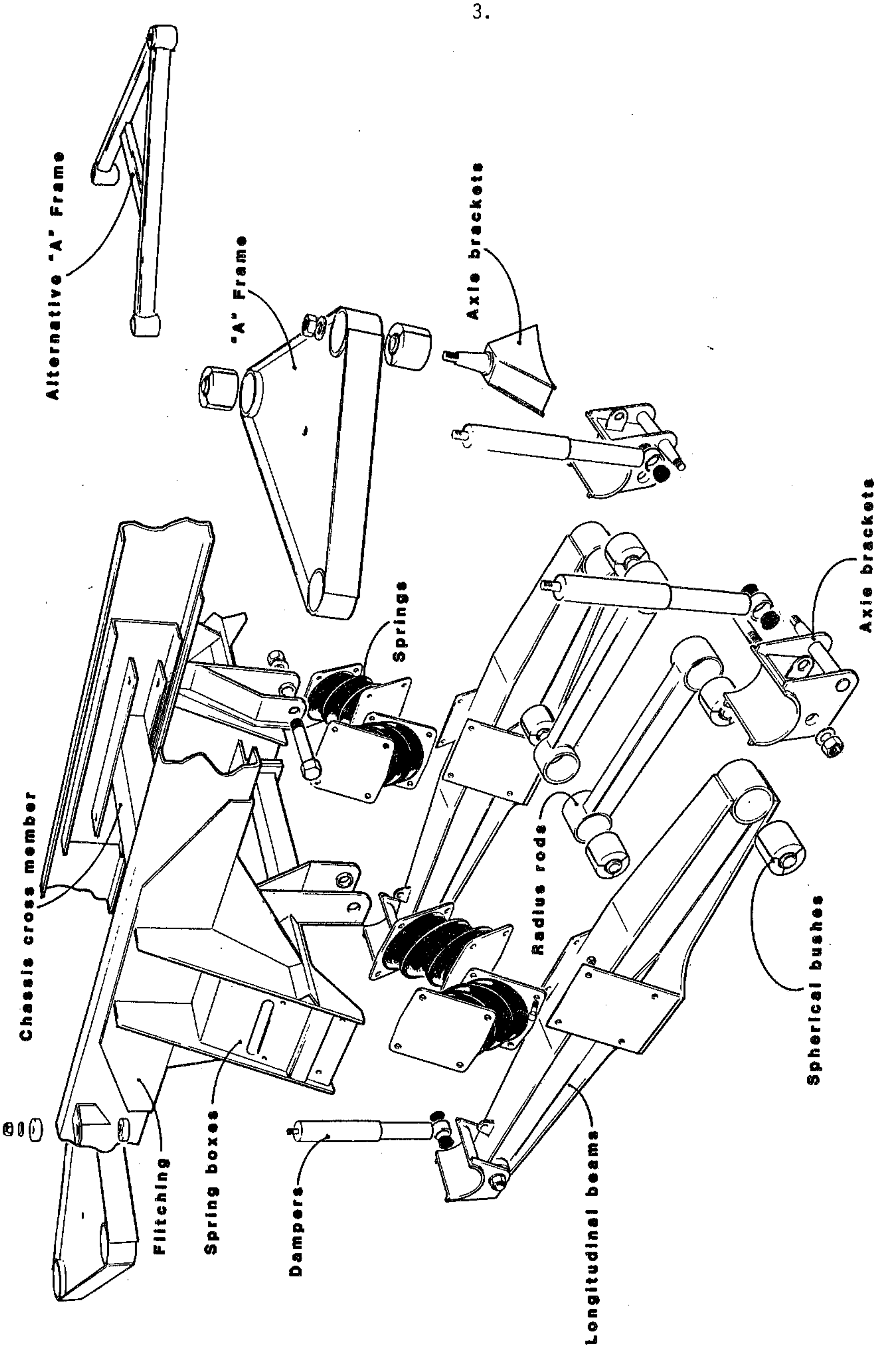


FIG. 1 EXPLODED VIEW 20 TONNE UNIT

1.3 Balance Beam Suspensions

In this type of suspension the two axles of the tandem are connected by a pair of longitudinal beams. These beams are pivoted at their centres so that under static conditions the load is spread evenly between the two axles. The springing for the axles is usually provided at the central pivot. This means that the deflection of one axle relative to the other is twice the deflection of the spring and the effective stiffness at one axle is one-quarter the stiffness of the spring.

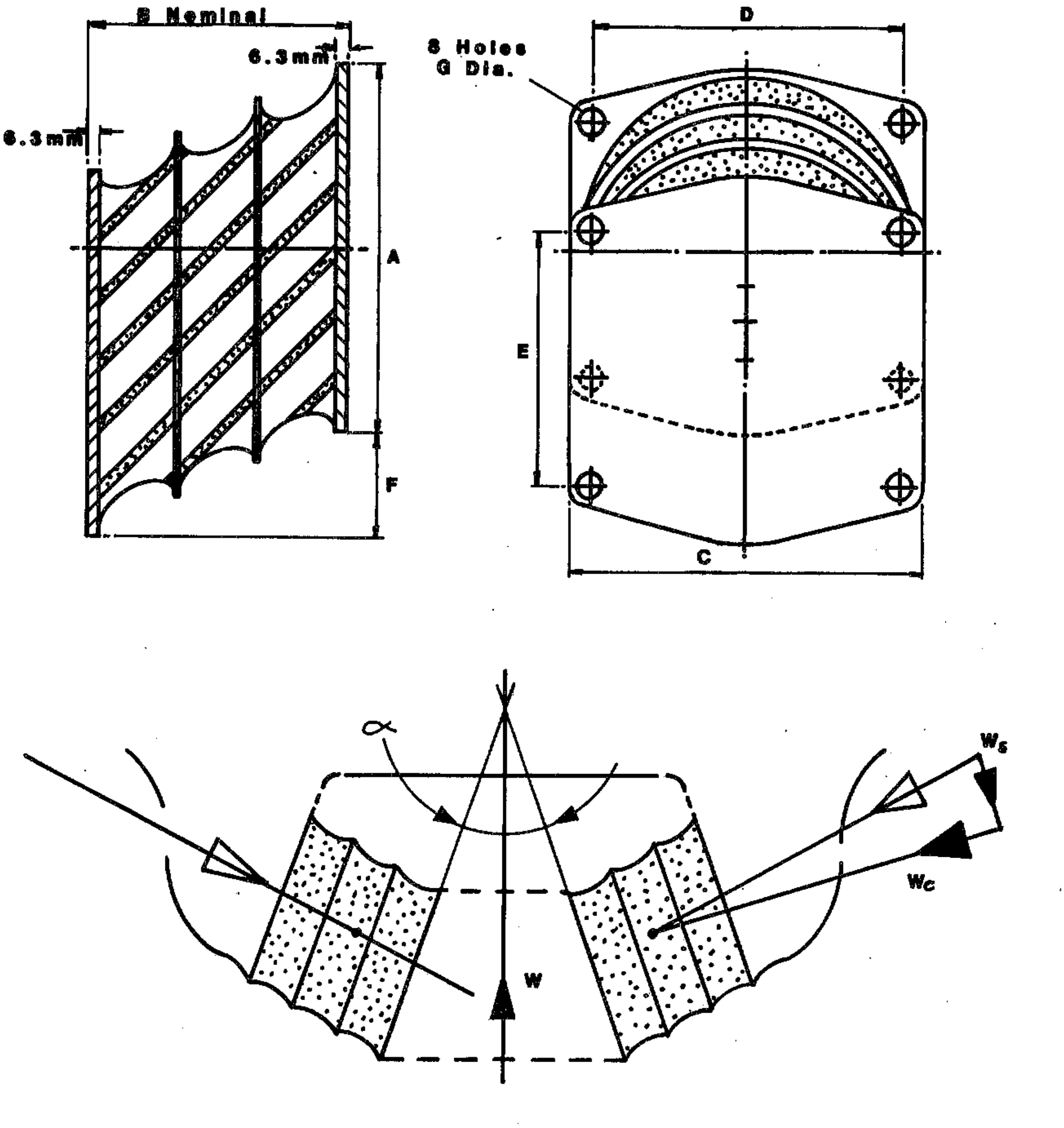
1.3.1 Rubber Springs

In this project the springing was to be provided by rubber bolsters (see figure 2). In these bolsters the rubber is loaded partly in shear and partly in compression. Since the stiffness in compressions is about 12 times greater than the stiffness in shear it is possible to vary the overall stiffness by altering the angle of the bolsters.

2. SETTING PARAMETERS

2.1 20-Tonne Suspension tests

Before we set about designing the suspension we took a 20T suspension of the same type. To this we attached accelerometers and strain gauges (see figure 3), twenty strain gauges were fitted. This was done to find the total behaviour of the suspension and the areas of maximum stress. The suspension was run through a test programme which consisted of a series of static and dynamic tests. These included positioning the truck over ramps under varying combinations of wheels (see figure 4). It also included driving the truck over a road circuit with a wide variety of surfaces,



Dimensions in millimeters						
A	B	C	D	E	F	G
196.8	139.7	196.8	174.6	142.9	69.8	11.5

FIG.2 RUBBER BOLSTERS

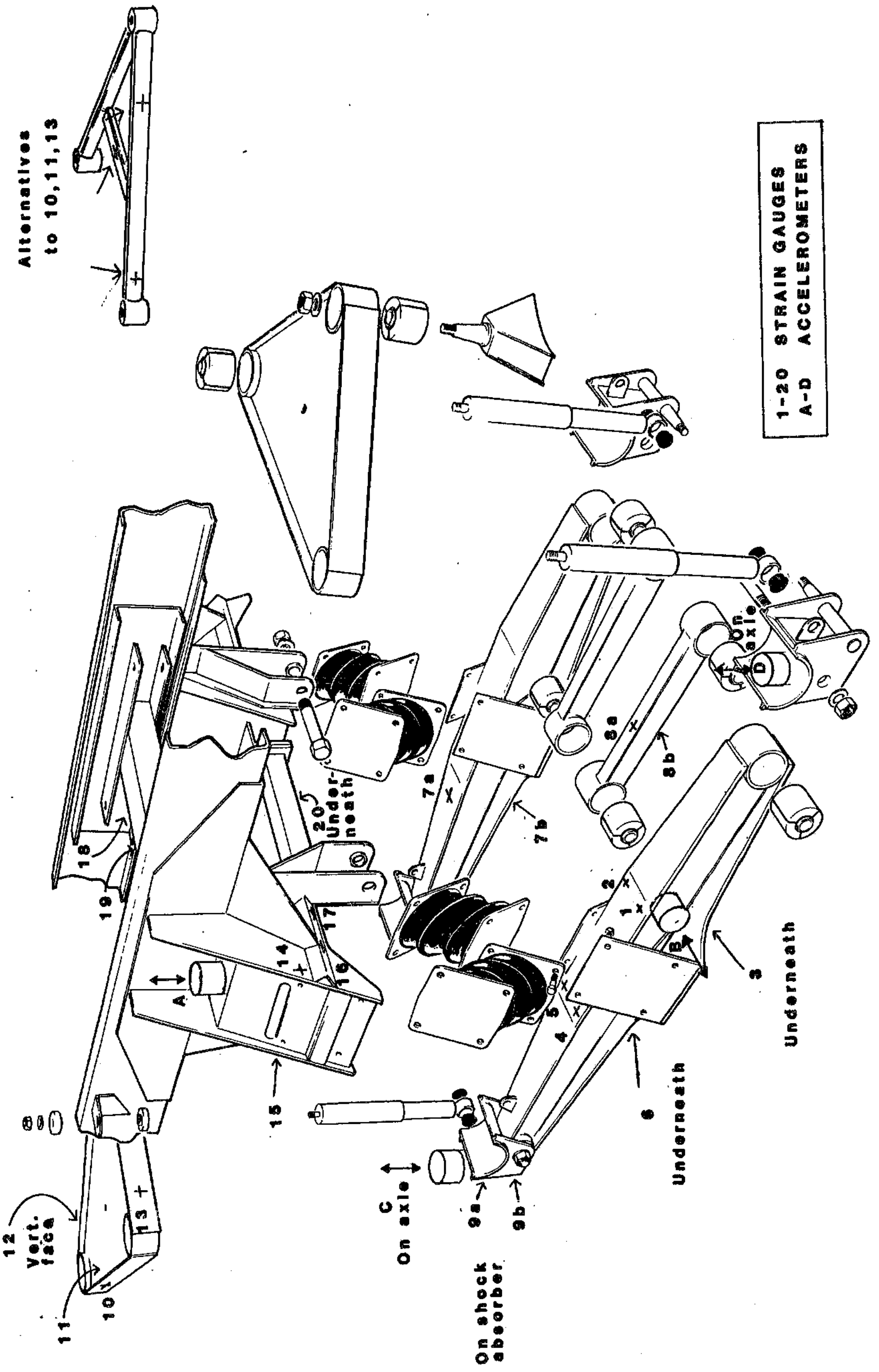


FIG. 3 STRAIN GAUGE AND ACCELEROMETER POSITIONS FOR INITIAL TESTS

CROSS ARTICULATION OF TANDEM AXLES

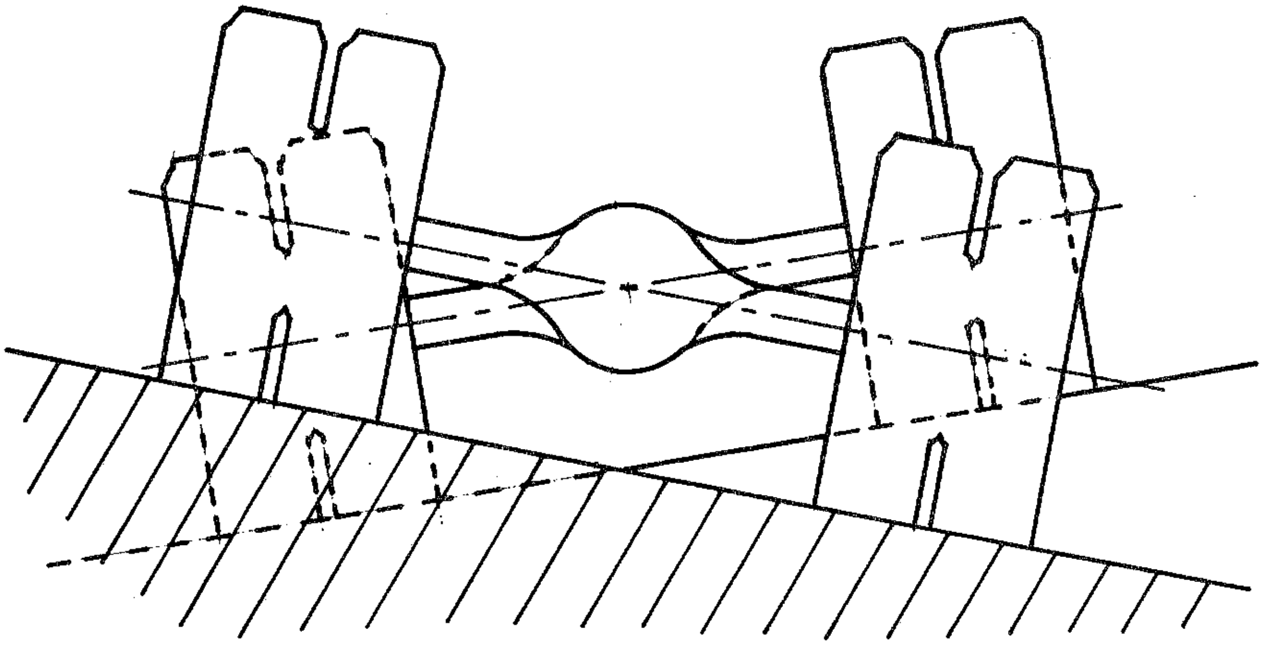
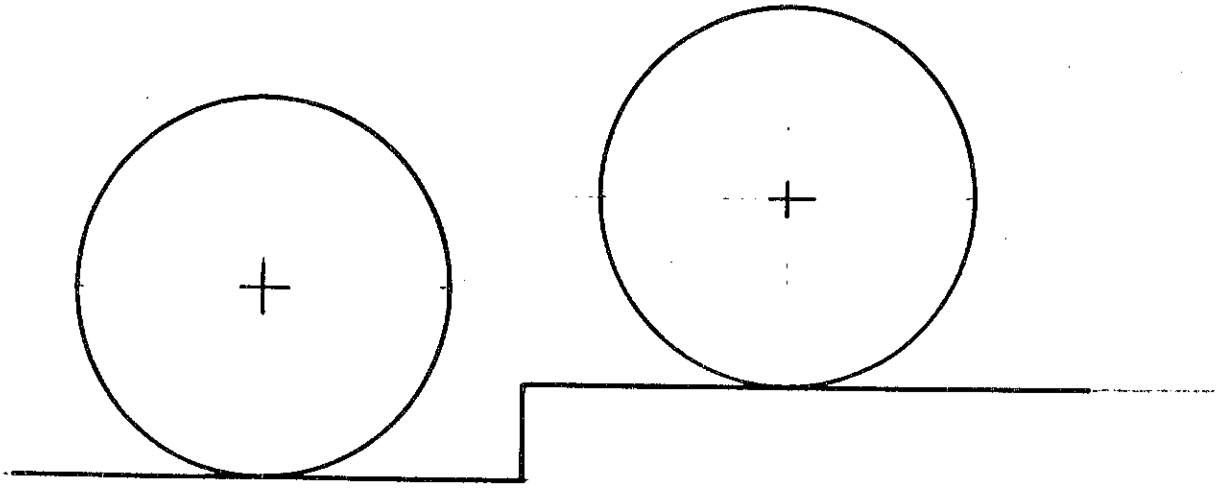


FIG.4



PARALLEL ARTICULATION OF TANDEM AXLES

cornering tests, braking and acceleration runs and driving the truck over a 50 mm high obstacle at varying speeds. The signals produced by the strain gauges and accelerometers were recorded continuously onto a multi-channel FM tape recorder. Analysis of the tests set the parameters for the design of the lightweight suspension.

3. PROTOTYPE DESIGN

3.1 Spring Rate

Our first step in the design was to choose what spring rate should be used for the suspension. For this we looked to the original British design. This was designed for 20T with a vertical deflection of 45 mm with the maximum sprung weight. This would give a natural frequency in bounce of 2.4 Hz. Our aim was to produce the same ride with a maximum load of 14.5T. To achieve the correct spring rate using the rubber bolsters which we had chosen the included angle was set at 40°.

3.2 Overall Layout

With the spring rate and bolster angle fixed we then looked at the overall layout of the suspension. What we knew so far was that the two axles would be connected by two longitudinal beams sprung at the centre. It was then necessary to decide on how the axles would be located. Ideally the axles should be allowed to move freely in the vertical direction and with freedom to articulate freely with respect to each other. However, the axles should be restrained in their movement sideways and fore and aft with respect to the chassis. As well as locating the two axles the suspension must cope with the torque reactions resulting from braking and acceleration.

The chosen arrangement used two A frames with the apexes connected to the tops of the differentials or axles leading back to the central cross-member. These provide the lateral location for the axles while still allowing vertical movement. Fore and aft location was provided by these A frames as well as two short links connecting the beams and the spring boxes (see figure 5).

3.3 Suspension Geometry

While we were arranging this layout for the suspension control links there were a number of things which we had to keep in mind. Firstly it is essential for tandem drive units that the differential angles should vary as little as possible between empty and fully laden conditions preferably less than 3° and in the same way the changes in drive shaft angle should be minimised during bounce and articulation (see figure 6).

Secondly the beams should have a minimal amount of movement fore and aft between the empty and fully laden conditions. Any movement of this type can lead to roll steer. This is because when the vehicle corners there is a weight transfer to the outside of the corner. The difference in load on the left and right hand side would then result in a difference in fore and aft movement between the right and left hand sides of the axles - which results in a steering of the two axles. This can have an effect on the yaw stability of the vehicle.

Thirdly we had to consider the height of the roll centre. In this particular set-up the roll centre coincides with the connection between the A frames and the differentials. The height of the roll centre effects two things: the higher the roll centre the shorter the distance to the centre

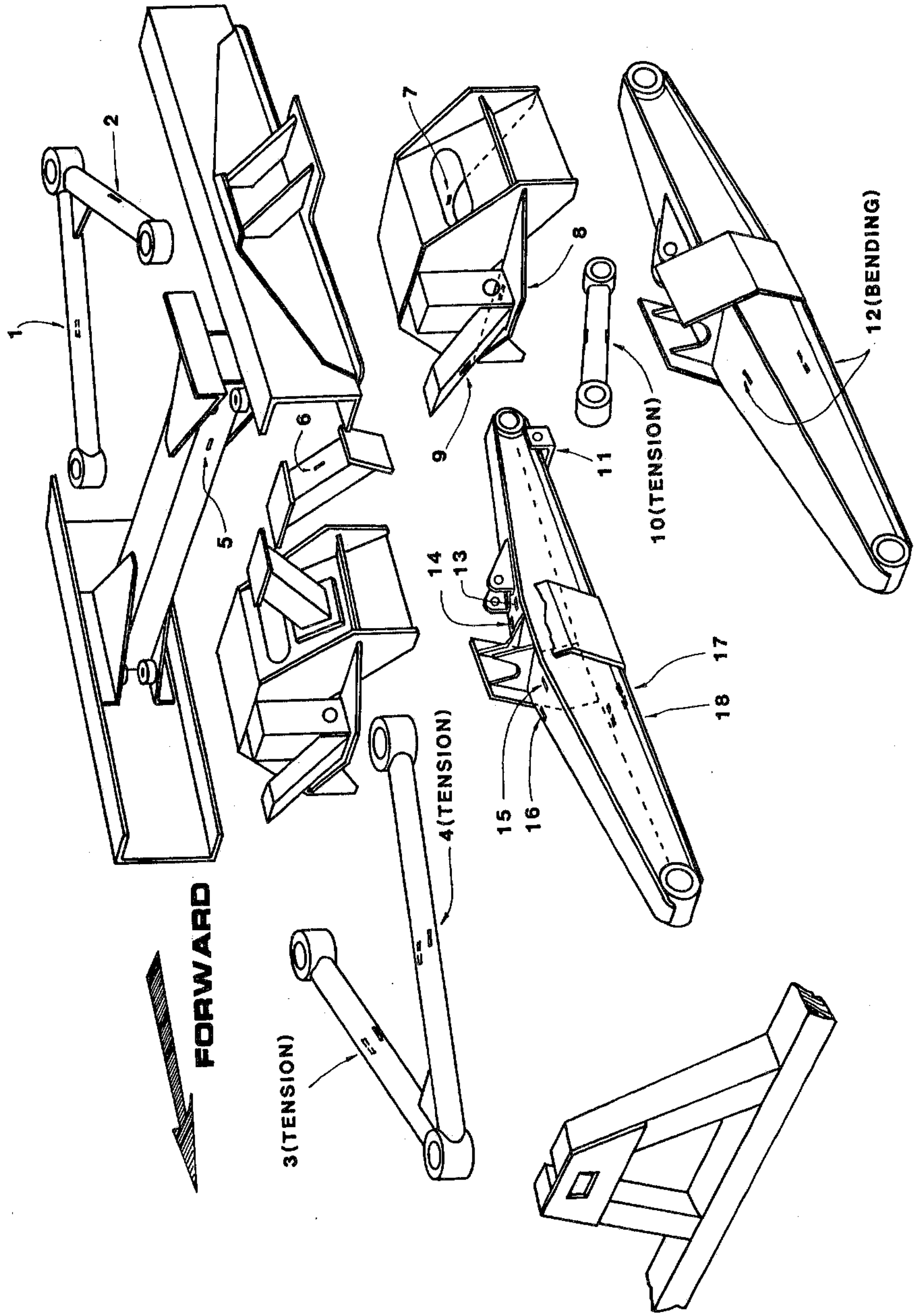
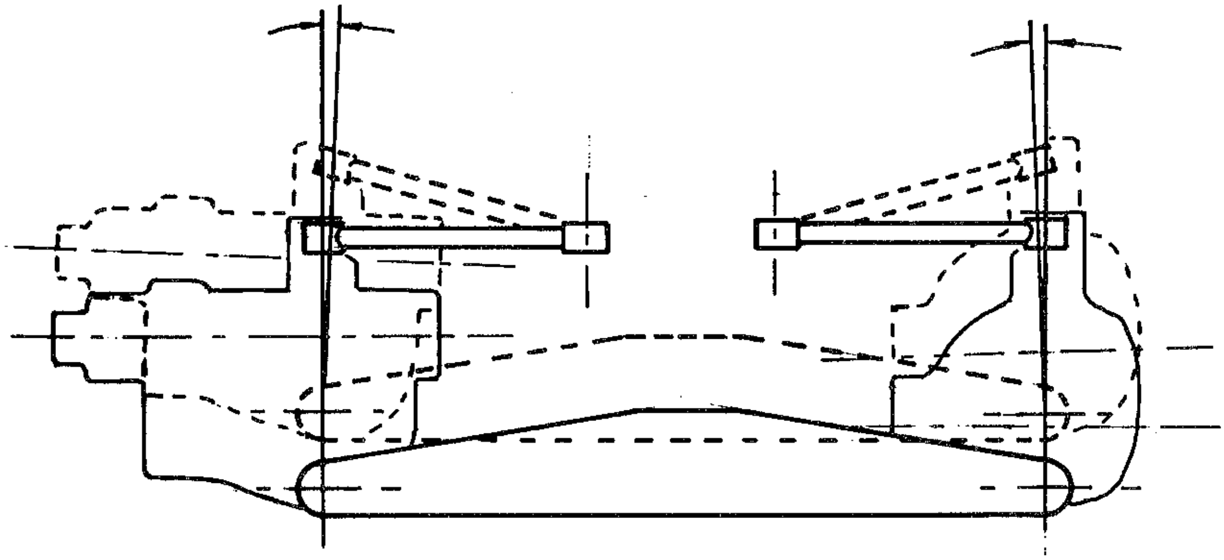
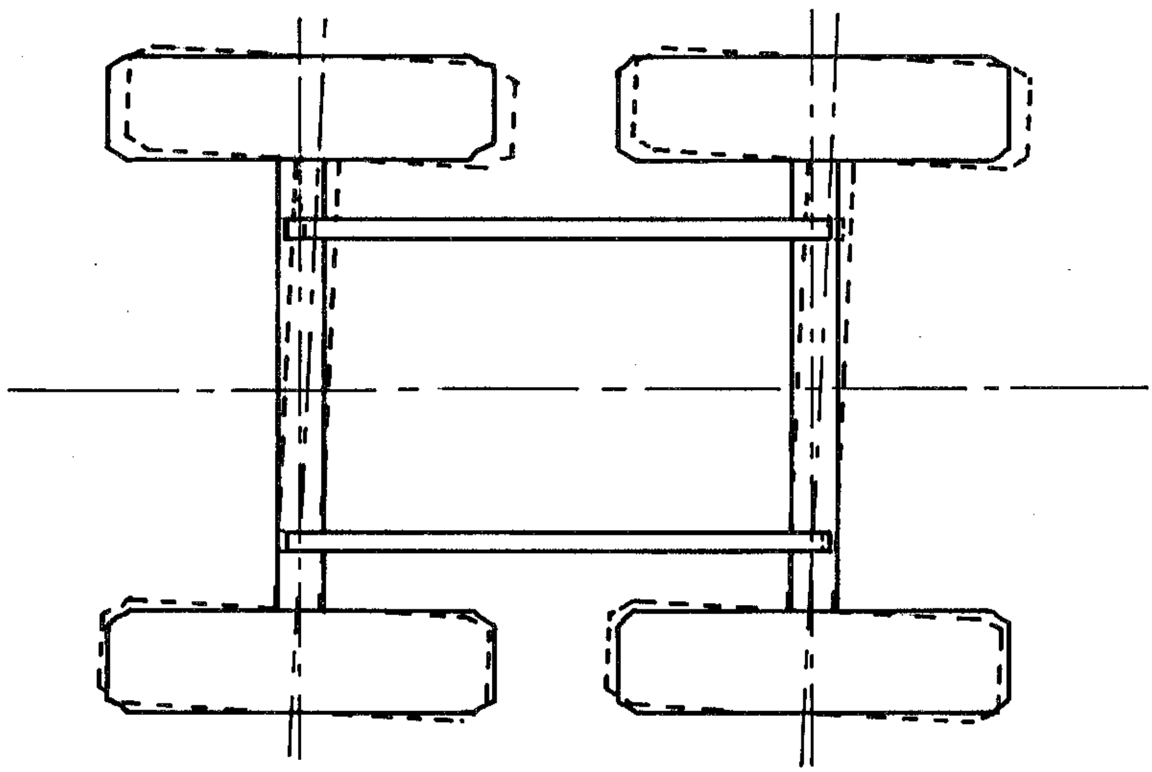

FORWARD
1
2
3(TENSION)
4(TENSION)
5
6
7
8
9
10(TENSION)
11
12(BENDING)
13
14
15
16
17
18

FIG.5



CHANGES IN DIFFERENTIAL ANGLE

FIG.6



ROLL STEER PLAN VIEW

FIG.7

of gravity and the less the rolling moment and so the less body roll when cornering (see figure 8). However, increasing the height of the roll centre also results in an increase in bump steer. In this type of suspension the roll centre is relatively high, which therefore results in a minimum of body roll. This advantage was considered to outweigh the effects of bump steer which also resulted from the arrangement.

3.4 Suspension Loads

Designing the size and shape of the suspension components involved a combination of methods. Much of the loading information was taken from the data gathered from testing the 20T suspension. The loads were scaled from these original tests and then applied to a 14.5T suspension. These loads and stresses were also compared to theoretical values which were calculated from first principles and much of the detail design drew on past experience which had already been gathered by the Division on suspensions and chassis.

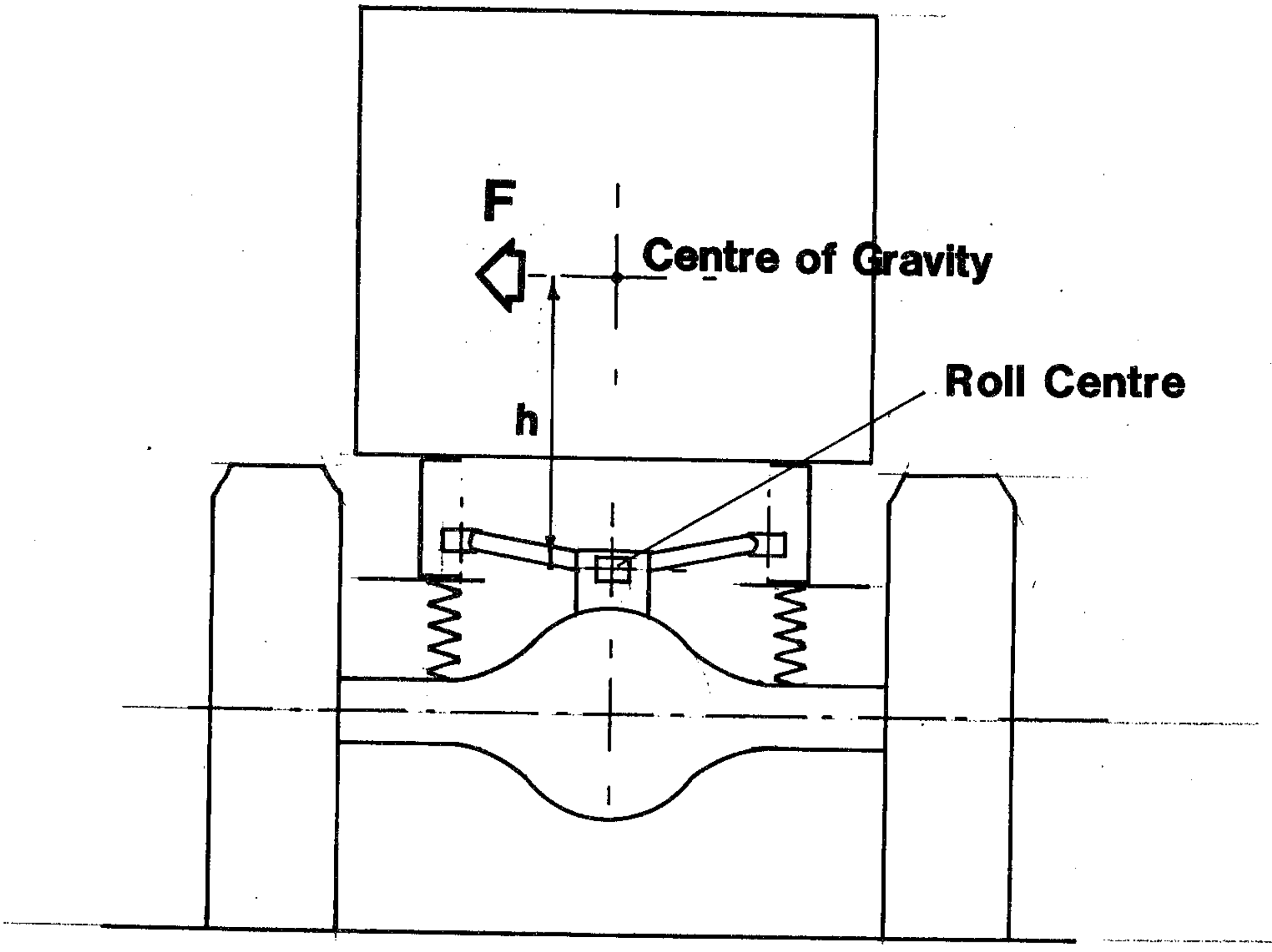
The principle loads which are applied to a suspension are:

(1) The static load - in this case, the maximum sprung weight, i.e., 14.5T minus the weight of the axles, wheels, brakes and tyres, balance beams and half the weight of the A frames etc.

(2) The dynamic loads due to bumps and impact loads from road irregularities.

(3) The braking and drive loads (although the drive loads are not so relevant for trailer suspensions).

(4) Cornering loads. These loads are due to the lateral acceleration which tends to push the mass of the vehicle to the outside of a



ROLLING MOMENT = F x h

FIG.8

corner. At low speeds in this type of suspension there is also the effect which results from dragging the tandem bogey across the ground as the vehicle turns.

3.4.1 The Static Load

This was used as the starting point in the design of the balance beams and the spring boxes. Our original testing showed that we should aim for a nominal maximum stress under the static load of 100 MPa. In the case of the balance beam this had been achieved in past by building an I section beam which tapered in elevation from the centre out towards the ends. In this design this basic section was modified so that there were actually two webs, making the beam a sort of box section which increased the beam's lateral strength.

The spring box structure was designed to accept the horizontal transverse components of the loads which result from the angled set-up of the rubbers. The vehicle load was fed from these boxes into the chassis through wide brackets whose web tapered from the centre out towards the ends. It was essential to spread the loads through these brackets to minimise stress concentration in the chassis rails.

3.4.2 Dynamic Loads

The dynamic loads due to bumps and impacts reached a maximum of about 2.5 g in our test units so the balance beams and the spring boxes were designed to take this sort of load before reaching the maximum allowable stress.

3.4.3 Braking and Acceleration

Braking and acceleration (or driving) loads are taken mainly by the A frames and the lower torque rods (see figure 9). These loads are very similar in nature but are opposite in direction. In most cases the maximum torques are limited by the traction of the tyres. The braking loads have the effect of putting the lower torque rods in tension as well as trying to roll the axles or differentials forwards - which is why the front A frame goes into tension and the rear A frame goes into compression.

Of course if the suspension is on a tandem drive unit, we have the opposite effect. Under acceleration the lower torque rods go into compression, the front A frame goes into comression and the rear A frame goes into tension.

3.4.4 Cornering

Finally we have the loads due to cornering. At higher speeds with large radius corners we have centripetal acceleration which causes weight transfer to the outside of the corner and body roll. In this type of suspension this produces a lateral load on the A frames which puts the links on one side in tension and on the other side in compression (see figure 10).

This type of cornering also puts extra loads on the balance beams. Since the body rolls; the springs are put into extra compression and shear on the outside of the corner and different amounts of compression and shear in the other positions (see figure 11). This means that the beam on the outside of the corner has an increased vertical load and the beam on the side of the corner has a decrease in vertical load.

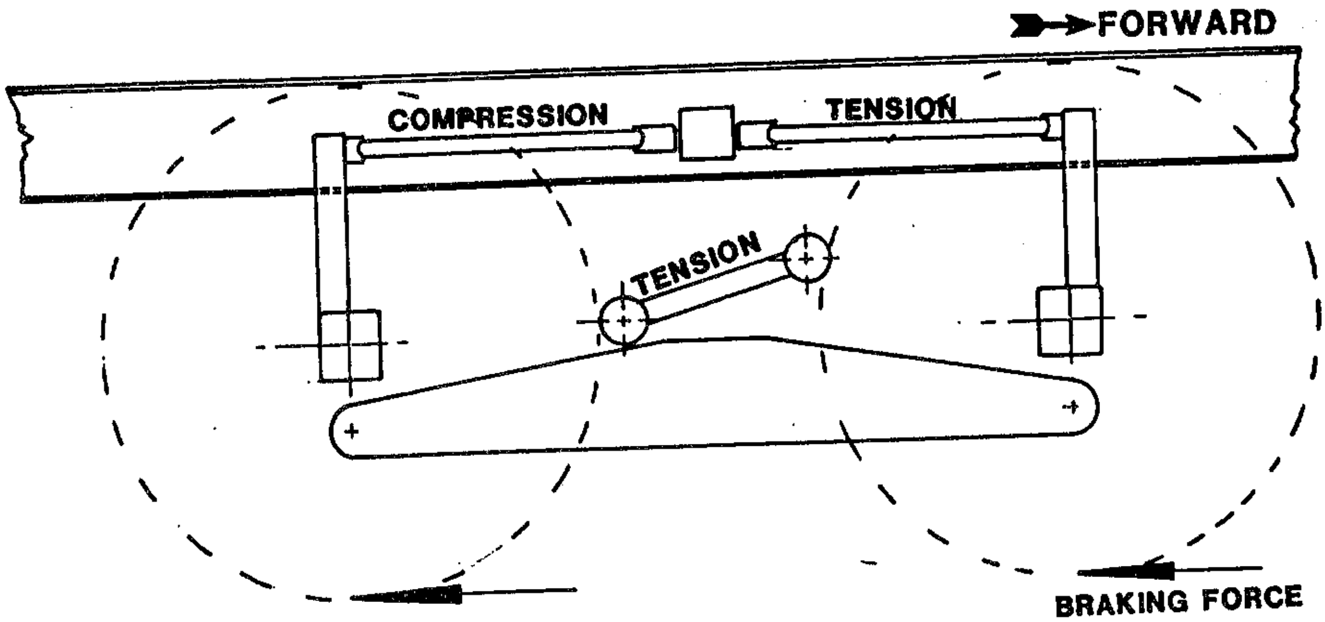
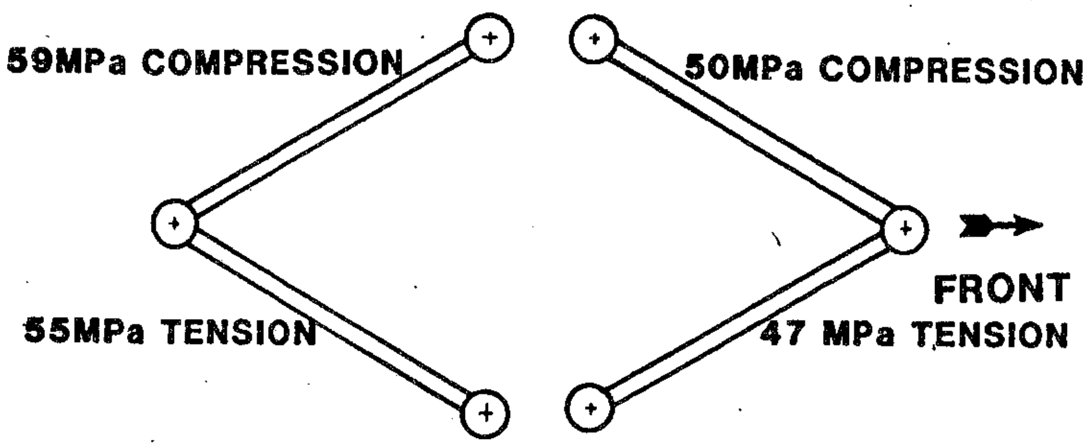

FORWARD
COMPRESSION
TENSION
TENSION
BRAKING FORCE

FIG.9

FIG.10


59MPa COMPRESSION
50MPa COMPRESSION
FRONT
55MPa TENSION
47 MPa TENSION

There is also a lateral load on each beam due to the action of the springs, which results in bending of the beams about the axis shown in figure 12.

Payloads with high centres of gravity can produce very high lateral loads which is why this suspension used box-section type beams.

With low speeds and tight corners the loads are quite different. The centripetal loads are relatively low but there are now high loads due to the massive tyre scrubbing necessary to turn the rigid body. This produces different loads in the A frames. These are shown in figure 13. In this test the U turn produced more than five tonnes of force dragging the tyres sideways over the road (figure 14).

4. CONCLUSION

Testing of the production prototype indicated that we had been fairly accurate in the design of the suspension. In most cases the stresses of the suspension components were close to what we expected.

What remains is the analysis of the dynamic behaviour of the suspension with respect to vibration and ride. This is currently underway and is being undertaken by the Vibrations Section of AIDD.

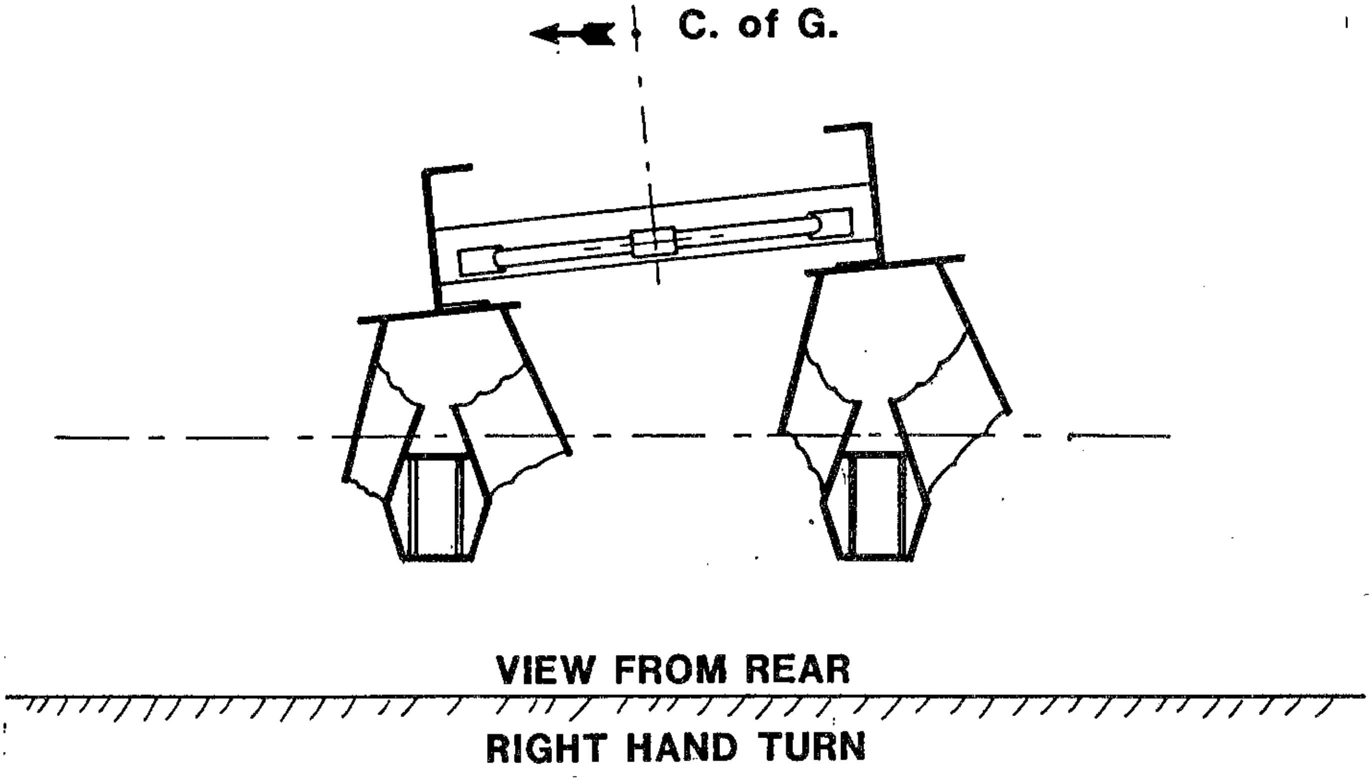

C. of G.
VIEW FROM REAR
RIGHT HAND TURN

FIG. 11

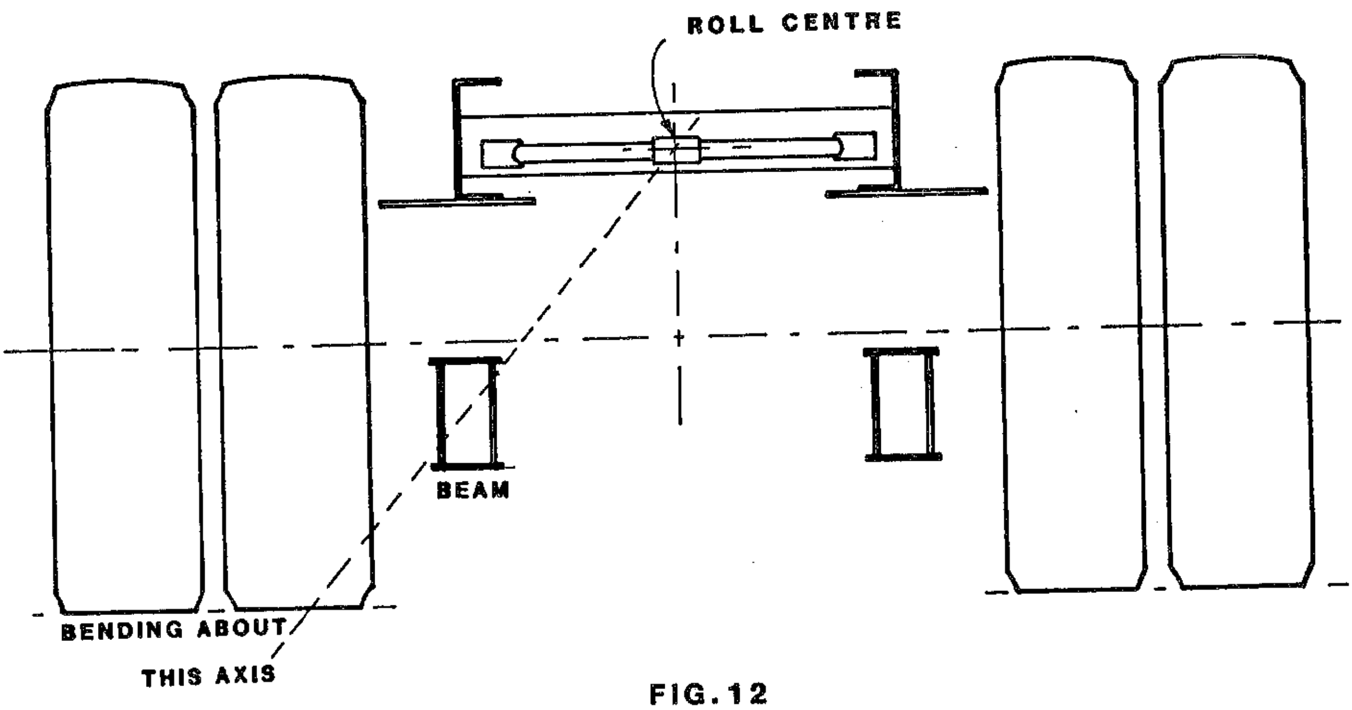

ROLL CENTRE
BEAM
BENDING ABOUT
THIS AXIS

FIG. 12

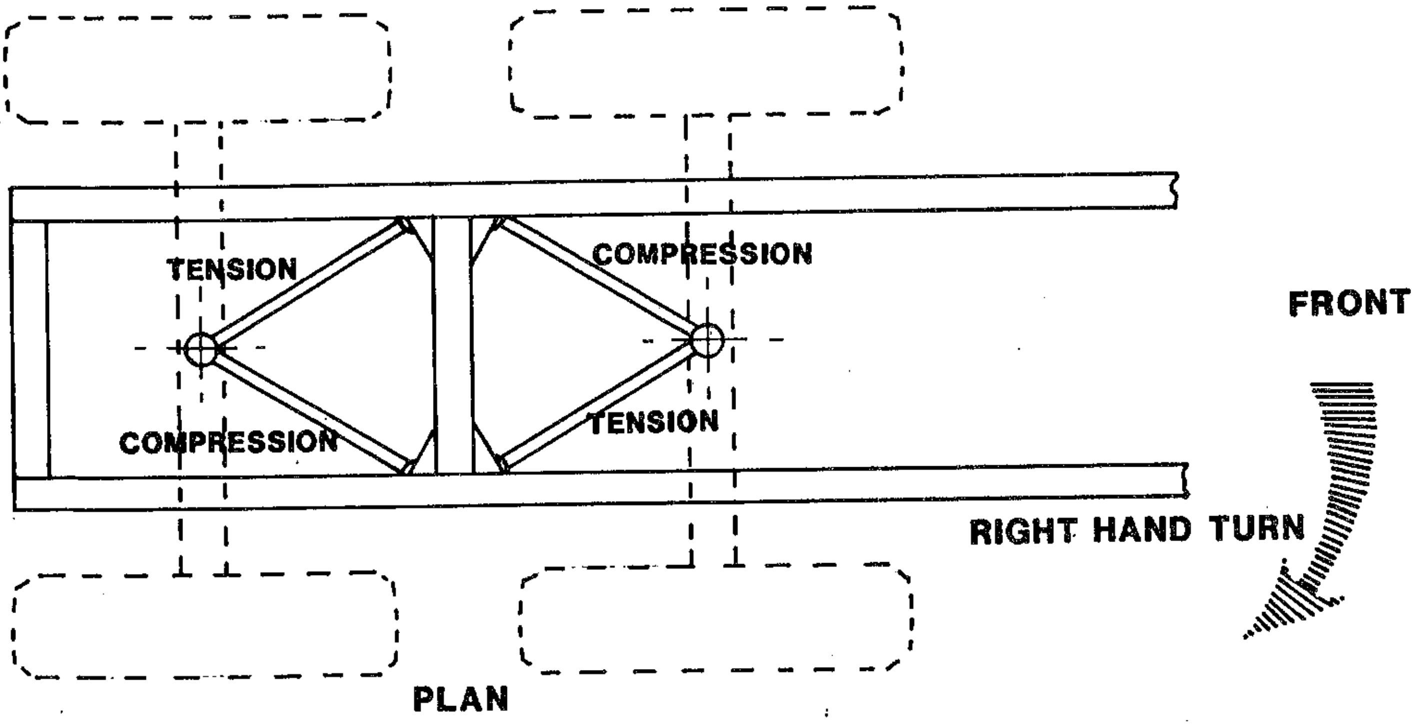


FIG. 13

An actual right hand turn (U turn) produced the stresses as shown in figure 14.

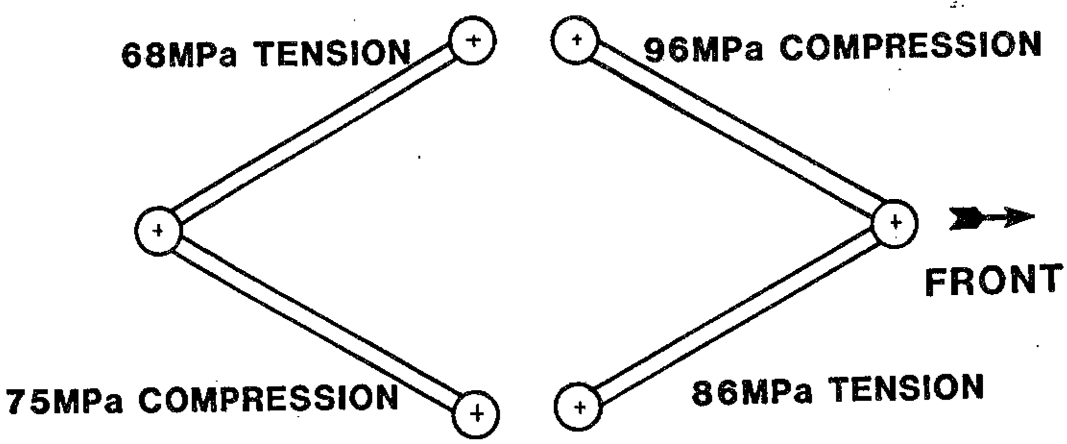


FIG. 14

These stresses indicate that a load of 53 kN (5.4 tonnes) would be placed on the differential bolt.

SESSION G - DISCUSSION PERIOD

P. Sweatman

I should say that a few other people working in this area have done a bit of work on that and he might want to comment on it, but in Australia anyway when we come to setting out size and weight limits for trucks we are more concerned about pavement effects than any other country in the world. That is the impression I have got from travelling around this year. I think that is because of the peculiar situation of long distances and low cost road making materials and just about all our road system is chip seal which you have here too here I think, and I think it is fairly susceptible to load. Our loads are like yours here in New Zealand, relatively low compared to the world scene, and I think that is the real reason why we have got involved in this to the degree we have.

J. Wilkinson

Thank you Peter, questions please.

R. Law

My question concerns trailer suspensions. The most common trailer suspension type operating in New Zealand has a very small deflection based on the American practice. In Europe the philosophy is a much greater deflection in the trailer suspesion. Perhaps Mr Tyrrell will be able to comment on the relative benefits of these two approachs and what effect does it has.

B. Tyrrell

I have just come back from the Frankfurt Motor Show and I can agree with you 100%. I would be very interested to know what is going to happen with a European Japanese tractor with a 3½-4" deflection and North America suspension that give 1-1½ inches. All I can tell you is that Britian is probably the worst place and there I have seen more broken equalisers cocked at that angle because of the deflection on the tractor. I am very much swayed towards the more greater development in parabolic springs in Europe. I think we may have to look at that, certainly in North America, and you may have to here. Its a much better designed spring, it will give better deflection, it has beautiful characteristics as far as I can see. All you are going to have to put up with is cost. You have to weigh that against life. You can talk about life cycles that are out of sight as far as North American springs are concerned. So if you look far enough down the road and say that you are going to change only one spring instead of ten maybe it is not a bad move.

The North American type spring is absolutely suitable for North American conditions. You got a smooth highway and you are travelling long distances and it is alright. But if you have a pavement damage situation and if you have long highways and small population, I think we can say the same in Canada, you have got to look at pavement protection and I think we have to improve springing on trailers.

N. Peterken

This one is directed to Peter. You plan to increase your weights in Australia to 20 tonne over a tri as I understand. Also I believe that it is common practise over there for them to pack the centre axle to get more load on the centre axle than front or rear. What bearing does this have, then, on road wear pavement scuffing and that type of thing. Is it a good practice?

I had forgotten about that but I have heard about that. I know trailer manufacturers do, some have said to me that they have done it in the past. I don't know what they are doing, but they are getting it right on the centre axle because a load on the centre axle usually weighs out pretty well. Whether on the testing we did with our wheel force transducer or the stuff we get from just running on the trucks over low speed weighing systems the centre axles are the least of our worries. If they are doing that they should keep on doing it because the load is good on the centre axle. It is the leading and trailing axles that are the problem. Whether that is caused by this peculiar inclination problem, variation in 5th wheel heights or various other factors I don't know but the centre axle appears to be pretty good.

N. Peterken

What about the surface scuffing on the tight corner.

P. Sweatman

Well that happens and it is probably more of a problem for the tyre wear than anything. As far as the pavements are concerned I mean we see a little bit of evidence in the city areas where you get some bitumen moved sideways, but that really is only a problem when you get to the stage where there is some structural defect in the pavement so that water can get in. Water is the worst enemy of granular pavement. So as long as we don't get to that stage we really don't see that as a major cost factor as far as wear and tear on the road is concerned. We are more worried about the structural damage to the pavement caused by the vertical load rather than the shear force.

P. Hassan

The packing under the centre axle is done to create the situation where the centre axle becomes the master of the situation so that the forward and trailing axles pivot around it because that reduces the enforced slip angle which tyres have to take. If for instance the vehicle pivots around the front axle, the slip angle of the third axle is twice what the centre axle will be and the rate of wear increases as the cube of this angle. So bring those slip angles down to a minimum to which you require to make turn around as near as possible.

I. Anderson

That study where you compared the different suspension of the configurations the Ridewell suspension seemed to look particularly nasty. Was that suspension damped?

P. Sweatman

No. Definitely not. Some suspensions respond more to speed when you look at it in detail. That one responded to roughness. As soon as it got a little bit rough that one started going crazy. It has got a lot of unsprung weight so it has got a lot of weight to fling around, and the spring rate of the thing, it was a high rated suspension because I think it was about a 44,000 lb unit that they gave us to test because they felt that that was the one they would sell in Australia for Australian conditions. But even so the spring rate is relatively low and if it had dampers it would have behaved fairly well, but it went crazy.

P. Williams

The type of suspension that Richard Wong has explained to us, the rubber suspension, is obviously a considerable change away from the heavier conventional spring suspension. I just wonder what the panel as a group believe is the potential in the future of that rubber suspension.

B. Tyrrell

I feel fairly safe in taking this because we don't make rubber suspensions. That let's me off the hook to start with. This type of rubber suspension, or at least rubber suspension comes in many forms. I am familiar with the Ridewell, I am familiar with the Nord which is probably the premium on in the United Kingdom. This is a derivative from that. Now the Nord probably has the best characteristics. It would be interesting to see if you had tested it because it uses in rubber compressive shear. It has a self damping effect, and it gets a self levelling effect too because it doesn't want to tramp like some of these do. This one has no reason for the axle not to move. The Nord does. As soon as one goes up it gets a greater resistance to bring it back down level. Our other experiences in Canada of course are with the Chalmers which is a rubber ball. You would have had a hell of a lot of fun with that if you had taken it on your tandem. Your vehicle probably wouldn't have come down yet.

J. Wilkinson

It looks like that is the only comment you are getting.

J. Britton

I would like to ask the members of the panel for each of the various countries they represent what they see as being the generally suitable deflection that should be available from the spring in term of maximum load versus the static load. In other words that for New Zealand I get the impression that if you have a spring that is capable of taking 2.5 times the static load then it may be acceptable for conditions over here.

B. Ervin

I'm not sure I understand it, and if I do understand it I'm not sure I know what the answer is.

J. Britton

Shall I try again? Okay.

What would you suggest as being the maximum load due to dynamic forces on the axle before the spring would compress to such an extent that it would hit the bump stop.

B. Ervin

I don't think I have ever done work that speaks to that but Peter presented something the other day on his measurement of 5th wheel loads in the road train that had 3 gs down and 1 up. That is the only thing that I have heard present here. beside from that I have never done any work that can permit me to comment.

I would say that it is very difficult to generalise on. For your average haul road load is fairly low C of G I would say without exception, but if you get cattle haul trailers then you have got to cut down on the deflection or it is going to roll. It is really a condition of application more than anything else. We have a fairly strong theory that we put on a fairly high arch spring which will give about 1½ or 2" deflection rated load which is about 10,000 lb, but the moment we get a high C of G, be it a tanker, a meat railer is the worst because of the swung load, we go to a low arch spring and considerably stiffer. So you have to compromise. I don't know that you can overall say we will give it so much deflection, 3" would be a good thing, because if you get 3" on some and you get onto some of these violent corners you have here you are going to finish up in the valley, I'm sure of that. I don't think you can generalise on spring deflections.

A. Kennaird

Looking at it from the pavement point of view we don't really consider what happens inside the black box itself. If I take just a straight engineering point of view of having to look after the road what we are interested in is what loads are applied to the road. How they get there is a bit of another matter. So when it comes to looking at suspensions we would tend to think that a load sharing suspension should at least be able to work within plus or minus 10 percent of load share, and that would help control the amount of loading that going on the road. That way we should be able to excessive loads. That has a spin off all the way down to the amount of road damage that could occur and the amount of costs to repair the road and keep it running at the serviceability limit that people want to operate at.

P. Sweatman

I think from the test programme that I was talking about, if you want to express it in G, the biggest axle load is about 2½G and as Bob said in the 5th wheel stuff we measured about 3G but that was on rougher roads, but I think that 3G would be the maximum dynamic factor that you would ever get on any of those components. The other factor that I wanted to comment on was that we were looking at one of the self steering bogies, because you saw what happened to those beam suspensions when they are undamped with the walking beam, with the Ridewell and so on, what you have really got there is a big walking beam with 3 axles on it and it has got no damping and no spring restraint in its pitch mode either. So I reckon if we put a wheel force transfuser on one of those we would get some pretty interesting readings. We might even exceed 3G.

P. Stone

If I could just make a couple of comments, going back to the last question on drive axle suspensions as Bill Tyrrell would probably bear out the move in Europe at the moment is to go towards air suspended drive axles and certainly from the Frankfurt show I think that that you will see that Demler, Benz, DAF, Volvo, Scania are all now tending to move towards air suspended drive axles. The air suspension, a spring that is used on that is used as a trailing link and not as a spring. The air suspension is designed around the stroke of probably about 8", but needless to say you are not actually working on that sort of stroke in normal operations. So in terms of the future, if we are talking of drive axles, obviously I would like to say that in Europe air suspension seems to be the thing. I don't ever see air suspension completely replacing rubber suspension drive axles, or even standard, but I think it will become horses for courses, depending on what you want then you will have a choice of suspension and I still tend to believe that air suspension is the kindest to the pavement. Certainly the research which has been carried out in the U.K., limited though it may be, has tended to prove that. I think that shall we say that some of the practices within each individual countries as to how they use air suspension may well tend to reflect on its performance.

P. Sweatman

As I said the air suspension we tested we degraded to some extent because their shock absorbers. They would have performed much better and they would have been the best I'm sure. It is just the way it worked out. The general comment I wanted to make, I would hate people to get the impression that all the problems are with trailer suspensions because I think it is the other way round, I think the truck manufacturers have got a long way to go whichever way you look at it, whether you are looking at road loading, or whether you are looking at stability, and these guys don't seem to be that interested in it. I was at the FISITA EACEDA which is the international sort of SAE type meeting last year and a guy from Renault presented a paper. He had come to the same conclusions that we had and it was good to see that one truck manufacturer working in that area and admitting that there were some problems. So I think the state of the art trailer suspensions are way ahead of the truck suspensions and I talked to three European truck manufacturers this year and I said to them "what do you think it is going to mean to you if you can get these increased loads on a tri-axle with these air suspensions, what are you guys doing about it?" They said that - we don't think it applies to us. So I think they have got a long way to go.

A. Williamson

I was just wondering how much research has been done on 1.8 m spacing as that is what we are looking ahead for some of our configurations. Nobody has mentioned anything about this close spaces (a) the pavement damage and (b) the vehicle stability etc

B. Tyrrell

Was it a 2 axle suspension.

A. Williamson

2 or 3. We have a mixture here. We have got some configurations where we have a double axle and a 3 axle at 1.8.

B. Tyrrell

As far as wide spread is concerned, something else that came out from Michigan, that the standard spread in Michigan, Ohio and Indiana is 9 ft. It is one of the least liked suspensions in our factory, but it did give them 18,000 per axle. Since that time California now will allow a 10 ft generally it is to spread the load. It is a bridge formula requirement to spread it over the greater distances. Probably the most successful is the Ontario 6 ft spread in conjunction with an axle 10 ft ahead which gives it a tri and that is done specifically to break away from axle group legislation. In Ontario if you get three axles equally spaced it is a tri-axle group and you have got to equalise between all axles. If you make that odd spacing it becomes a single and a tandem group so you don't have to oscillate between those. So the first tandem is a spring tandem is a 6ft and then we would have to go 10 feet ahead of that to get the maximum. The maximum in Ontario is 66,000 lb on that tri-axle group, sorry tandem single group. You get nothing in Canada above the 6 ft. In Europe you get the 81 inch or the 2 m spread. Now you say that you have a 1.8. 6ft. So you have inherited basically the Canadian one which is the most popular. 75% of the tandems in Canada are 6ft tandems, be it whether they are converted to tris or not, and that was done purely and simply for pavement loading, bridge formula and so forth and they are very very happy now to give you the 44,000, but not with the 10% tolerance which you mentioned just now, it is much closer than that. They are not unhappy about the bridge or the road damage, in fact they are very happy. They have gone up from 18,000 on axles to 22,000 and they say they are getting much less damage now than they were previously.

P. Sweatman

I just wanted to make another comment. We were talking about the research they are doing in Canada in the size and weight study. One of the major thrusts of that research is axle spacing, both the tandem and tri-axle groups. They are looking at suspensions and axle spacing being the two major things they are looking at in their pavement test programmes so in a year or two we will have a lot more information on that. But just in general alot of countries have regulations which allow heavier loads on groups with wider spacing and that is really a bridge-type formula. This is what you are looking at. In Australia it is a bit different because we are so obsessed with the pavement that we tend to go the other way. We don't have regulations which are dependent on spacing but we have very close spaced groups and we encourage that. That really comes back from the old AASHO road test where they found that if you got axles close together you were better off pavement wise to some extent. If you got a fairly heavy pavement you don't get three independent deflection bowls, you get some overlap and you get some benefit from that. So you have got two counteracting things and it depends how much weight you put on your bridge formula and how much weight you put on your pavement damage as to which way you go. I think the Canadians are going to be pointing the way for us within a year or so.

P. Mathers

In your testing method you had for pavement damage did you find the direct correlation between the static loading sharing suspension and the dynamic damage to the road?

P. Sweatman

No, because some of the ones which have a very free pivoting system with no much damping and no friction and so on weigh out well statically, but they are the ones that go crazy when you go over a rough road at highway speed so I would say in general there is very little correlation between those two facets of suspension performance, both of which are pretty important.

N. Peterken

Addressed to all countries, the thing that concerns us here in New Zealand is the fact that we are fined or policed on axle weighing and there is one hell of a big difference in tandem, it doesn't really matter what type of tandem it is, and also tri-axle we are getting a great variance in weighings. So two questions, what sort of penalties and what tolerances have you got in each country and what is the answer? Are there problems with the suspensions or that way they are set up that you have found causes it?

B. Ervin

Are you just talking about all the things that add up to variations from axle to axle on an otherwise normally equalising suspension. We haven't been doing any work specifically in that area because we don't see any of those concerns poking into the vehicle performance issues of course. The only things that we confront, and rather frequently and more so now dealing with the Canadians because they allow air suspended axles, or mixed media as the Australians would call it, and that is a hot issue with us. It has to do more with concerns about abuse rather than concern about the mechanics, although the mechanics don't look good either. We have a frequent useage in Michigan of spring suspended axles and air belly axles under semi-trailers etc and as far as we know there isn't any way to do that. We have never seen anybody that had a good way to do that but it is one that plagues us and is the only area in which we are attentive to the matter right now. I should say that the US is remarkedly unconcerned and inactive generally on this whole issue of load distribution and certainly load dynamics. When Peter published his work a few years ago it hit us really hard. We thought it was amazing that the magnitude of variations that he was measuring and the apparent implications for pavement damage were tremendous and we went racing off to Washington to say look at this. This is some whole vast area that has been overlooked and there ought to be a great opportunity, because the researcher is always looking for new support you know, and so we thought it was an opportunity. This is what five years later, there isn't boo going on at the federal level. They paid us to do a little bit. We done some work to confirm some things that Peter did and to expand on some of the measurements and so forth but it is kind of a neanderthal outlook on the whole thing and very little interest in the whole matter as far as I can see. Except at some local levels. California has had some special interest in things but in general there is darned little interest in the whole subject.

B. Tyrrell

Neil was that addressed to the penalties of being overweight on an axle or the design overweight?

N. Peterken

Well both really. Because of some inherent problems in the design, the penalties, we seem to concentrate in this country more on the penalising that difference all the time and we can never really find out what causes it. Okay we now know that there is a lot of weighbridges around the place that are not quite level so that has become the best excuse we can think of at the moment, but it is interesting what Bob says, that they are really not too fussed about it. They don't seem to have the same policing as we do here.

B. Tyrrell

You sure better not have an axle overweight on Ontario now. The tolerance have been cut down to practicall nothing. It is around 200 lb that they are trying to get down to. I was wondering one of the things that I haven't seen a weigh scale here. Do you use roadside scales in New Zealand? One of the things that have got themselves a horribly bad name and is pretty well dead now is the mobile scales. Many of the truckers won't even pull over them. They say take me to a weighbridge because it will damage their transmissions getting on to them, they are inaccurate, you can prove them things wrong about nine times out of ten. So I am wondering what area of weighing that you are talking about. Shoot the guy with the mobile scales, they are useless, absolutely useless. I think I have an old report on this it is put out by the Americans, and it has all the arguments why those scales are not the slightless bit of use and the man that was supposed to come down here and give this talk has got several cases thrown out of Court on that very basis, that the guys who operate the scales don't know how to work them. The way out is we can make a suspension that will weigh out absolutely accurately, in fact we put adjustable radius rods to move axles on widespread and we can get within about 500 lb. But once that thing gets on the highway and the guy gets driving it it loses all its accuracy, there is no doubt about that, and the load can affect it of course. The big bug bear are the portable scales. The road scales should be pretty good now.

P. Stone

I suppose you could say that this has been the sort of thing that has been held over the UK truckers. The legislation does exist but it is never really enforced, and part of the reason for that has been that even the load equalisation systems that are used in the UK even on the mechanical systems are shown not to work, air suspension does give you better load equalisation. But at the moment in the UK it is not being enforced. There has been a lot of talk about roadside weighing, but I do a lot of driving in the UK and I am yet to see anybody pulled across. Now it does happen occasionally, and you do see a team or hear of a team that has gone out but it has not to my knowledge been any prosecutions that have succeeded. I think that is the point to make. At the moment that state of the art both on the authorities side and on the suspension side is really such that neither is prepared to go "into print" over it shall we say.

A. Kennaird

Looking at it from the Ministry of Works point of view we would like to see some sort of control on the amount of loading that goes on the road, and we believe that the portable scales used by the Ministry of Transport are really quite effective when they are used in a site that is up to standard and by people who know what they are doing. We can get very good precision out of that type of system, technique and equipment. I agree that weighing a vehicle up on the side of the road has a lot of inherent problems, particularly if the site is not too level, but what we really are looking for is what is the load on the road and the way our regulations are framed really say that those are the load limits that are allowed on the road. It doesn't say exactly what shape the pavement has got to be. There are some problems in weighing and the MOT and MOW are working on arriving more effective procedures and more acceptable equipment.

P. Sweatman

One of our biggest State road authority in New South Wales has got a million dollars worth of new Telube portable scales and we have gone to a lot of trouble to find out how to use these things without overweighing trucks. And also as you say without the problems of screwing tail shafts because a guy has to pull up six axles usually heavily overloaded up onto the thing all at once. And what we have come up with is a way of compensating for the error so if you weigh a tri axle on these high profile scales and the prime mover is on the level just on the road you will overweigh that tri-axle by up to two tonnes. And what we have done is come up with a computer programme which is dependent on the wheel base on the length and the shorter they are the worse it is, but dependent on that the guy can just look it up and we have a mandatory reduction so before he does anything he has to take that off the weighing. If they choose to weigh it the way Bill was talking about they could potentially screw the tail shaft off. You don't have that problem and wouldn't have to subtract it so the truckie will have the option which way he wants to be weighed. He will have to be weighed by one of them. But in the long term we want to get away from those but like I said we have a big investment in hem so we put a lot of effort into how we can use them properly. We think we have achieved that. We still allow tolerances on top of that but you can weigh on those things but you have to do it properly. We have a conference on this in December. We have just come out with some guidelines for these field guys. We are getting them altogether in Melbourne and maybe you guys should take up a collection and maybe Frank could come over and see what is going on there because it really is just coming in Australia now. We feel you can use these things but you just have to be careful about it.

J. Wilkinson

Time for one more question then lunch time.

F. Clissold

Most of our weighing is done in single axle pits so we are talking about low profile weighing platforms that we are keeping below 8mm above the highway.

B. Tyrrell

So you are just looking for an overload. You are not looking for balance between axles or anything funny like that.

B. McDonald

If I could direct a question to Peter. Yesterday you spoke of roll stability in tractor units and the suspension that came to the fore in that was the four leave suspension both the International and the Reyco one. Now I take it the reason for that was that the roll centre was higher on those suspensions than it was on the other ones tested. If this is the case to be ridiculous, the higher we can get that roll centre, in other words if we have a suspension, and I take it the roll centre is where the spring meets the slipper, is that correct? (Pretty well), so if we had a suspension that was mounted to the side of our frames and took them further up towards the load centre, would that be more suitable?

P. Sweatman

I don't know how far you can go with that. I think that Richard may have a comment on that because he said that you get a lot of bump steer or something when you have a very high roll centre. We haven't really looked into that. So there is obviously other factors. When you are talking about suspensions I've put the five factors that you are designing it for, there is a lot of things involved. We have found all sorts of funny things that happen. You can't just deal with with one and not the other. We would attribute the good roll performance of those four spring tandem suspensions primarily, they have got a pretty stiff vertical rate as well of course, so that is one factor. The roll centre is another one as I say, but I guess you have got to be a bit careful about bringing it up too high. But it certainly does have a benefit, but there are a lot of other things that you have to consider.

P. Baas

In Australia you have gone to approved suspensions. How much difference has that made in road damage. Can you put a percentage or a guess as to what the difference would be and what increase in weight would be allowed for those things. Is it worthwhile in actual fact?

P. Sweatman

Well we have this type approval, the Blue Book, and that has virtually no effect. Well it had some effect initially because it got rid of some wide spread tandems which we had some problems with, it got rid of all kind of tag axles and all those interesting little things that Bob Ervin would have liked to have had a look at when we took him around, they are not there anymore, they are all the same. So we achieved a lot of uniformity, but we have still got, as I indicated, problems. We have got problems with the tris because of the static situation, and we have got problems with the drive axles which weigh out well, which are good from a static point of view, but from a dynamic point of view they are disastrous. So we still have a long way to go. As part of this size and weight study we have just done we have got this model that we can get pavement costs related to roads and wear and tear on the road. And one of the things we were trying to do was put the suspension factor in as well. That's why we did all our suspension surveys and we went through the whole thing. But we sort of ran out of time and we didn't have time to do that. At some stage we would like to do it. It's hard to do it at the moment because really the pointy end in research in that area is trying to find out what the relation between the dynamic impact on the road and what is happening to the pavement is. You can make some estimates based on this fourth power law which indicate that you get a certain increment in pavement damage because you have got the time that the load is above the mean load is weighed out against the time that it is below the mean by its fourth power so the bit above is more important and you can work that out. But that ignores the fact that were you have a pavement profile you are probably getting the peak loads at pretty much the same place because most truck suspensions have pretty similar natural frequencies, both bounce and axle hop and so on. So you will probably find that that same bit of pavement is getting that big load, and it doesn't know if it is getting a big load off a walking beam, or whether it is getting a 20 tonne single axle load steadily running over the top of it. The research that is being done both in the UK at T & RRL and this Canadian stuff that we are all waiting for is going to give us a lot more information on that. But my estimation is that we are going to find that it is a lot more important than we think so any estimate that we make of the cost at the moment I think would be a pretty conservative estimate.